Name: KEY Date:_____ Block: ____

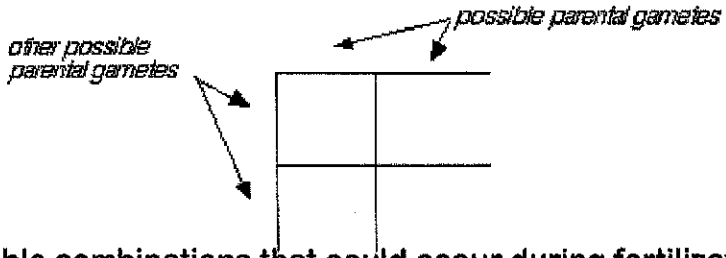
## Genetics Worksheet

**Introduction:**

*A major goal of science is prediction. When we can understand a pattern, we can predict the future. Once you learned that spring followed winter you would be able to predict that April will most likely be warmer than January. In genetics, we also try to predict the future. In making predictions (or solving genetics problems), it is very useful to follow the following five steps:*

1. Determine the genotypes of the parents or whatever is given in problem.

2. Set up your Punnett square as follows: *# sq. based on possible gametes that can be formed




3. Fill in the possible combinations that could occur during fertilization.
4. Write out the possible genotypic ratio of the offspring.
5. Using the genotypic ratio determine the phenotypic ratio for the offspring.

****On the following pages are several problems. With each new problem, one sample is illustrated, make sure you look over the sample.**

**PART 1: Monohybrid Crosses with complete dominance**

1. The following pairs of letters represent alleles of different genotypes. Indicate which pairs are **Heterozygous** and which are **Homozygous**. Also indicate whether the homozygous pairs are **Dominant** or **Recessive** (*note **heterozygous** pairs don't need either dominant nor recessive labels.)

A. DD *homozygous, dominant*
B. Dd *heterozygous*
C. dd homozygous recessive
D. ss homozygous recessive
E. Yy heterozygous
F. WW homozygous dominant

2. In humans, brown eye color (B), is dominant over blue eye color (b). What are the **phenotypes** of the following genotypes?

KEY
B = brown
b = blue

A. BB Brown
B. bb blue
C. Bb Brown

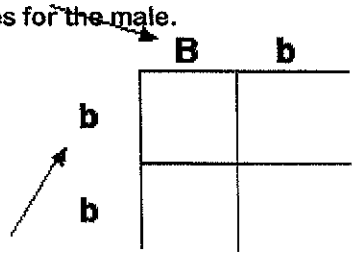
## Sample Problem (READ ONLY):

*A heterozygous male, black eyed mouse is crossed with a red eyed, female mouse. Predict the possible offspring!*

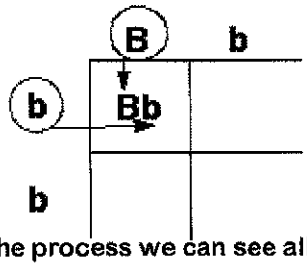
Step 1:**Determine the genotype of the parents.** The Male parent is heterozygous which means he has one allele for black eyes and one allele for red eyes. Since his eyes are black, this means that black allele must be dominant over the red allele. So the male parents genotype is Bb (B = allele for black eye, b = allele for red eye).

The female parent has red eyes, there is only one way to have this recessive phenotype, so she must to be homozygous recessive. Homozygous recessive means that her genotype must be "bb". Therefore, genotype of the parents is **Bb x bb.**

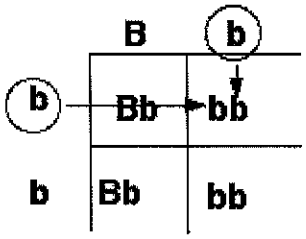
Step 2:During meiosis (formation of sex cells) one member (allele) of each gene pair separate. The male mouse (Bb) produces some sperm containing "B" (the allele for black eye) and some sperm that contains "b" (the allele for red eyes).
On one axis of the Punnett square you put the two possible gametes for the male.
Repeat this for the other axis for the possible female gametes.




Step 3:
During fertilization sperm meets the egg. The Punnett square show us the various **possibilities** during fertilization. The offspring must be one of these genotypes listed in the squares.




If the sperm contains a "B" allele and fertilizes the egg containing the "b" allele, the resultant offspring will have the genotype "Bb"




Repeating the process we can see all of the possible genotypes.

Step 4:
The genotypic ratio is determined by counting each possible genotype. You'll note there are two "Bb" for every two "bb". Therefore, we write the ratio as 2 : 2; Bb : bb

Normally we reduce to the lowest terms: 1 : 1; Bb : bb

Step 5:
The Bb will produce a black eyed mouse (phenotype) and the bb will produce a red eyed mouse (phenotype).
The phenotypic ratio is written as 1 : 1; black eyes: red eyes
***The ratio tells you there is an even chance of having offspring with black eyes as there is for having offspring with red eyes. That would be the same as a 50% probability of having red eyes, or a 50% probability of having black eyes.***

Ss ss

**3. A heterozygous, smooth pea pod, plant is crossed with a wrinkled pea pod plant. Smooth (S) pea pods are dominant over wrinkled (s).**

S = smooth
s = wrinkled

a. Determine the genotype of the parents. Ss x ss

b. Set up a Punnett square with possible gametes.

c. Fill in the Punnett square for the resultant offspring.

Ss

| | S | s |
|---|---|---|
| S | Ss | ss |
| s | Ss | ss |

SS : Ss : ss

d. What is the predicted genotypic ratio for the offspring ? 0 : 1 : 1

e. What is the predicted phenotypic ratio for the offspring ? 1 : 1 (Smooth : wrinkled)

f. If this cross produced 50 seeds how many would you predict to have a wrinkled pod?

4. In humans, weirdness (W) is dominant over normal (w). A man who is heterozygous for weirdness marries a woman who is heterozygous for weirdness.
a. Draw a Punnett square of possible offspring:

Ww

Ww

| | W | w |
|---|---|---|
| W | WW | Ww |
| w | Ww | ww |

WW = weird
Ww = "
ww = normal

b. What is the probability that their first child will be normal? 25%.
c. What is the probability that the next child will also be normal? 25%

5. In humans, free earlobes (F) is dominant over attached earlobes (f). If one parent is homozygous dominant for free earlobes, while the other has attached earlobes can they produce any children with attached earlobes?

FF x ff

| | F | F |
|---|---|---|
| f | Ff | Ff |
| f | Ff | Ff |

**Working Backwards**

Some times we only know about the offspring and we want to learn about the parents. If you have been paying attention, you should have started to notice a pattern. You begin by listing the known genotype of the offspring (usually the recessive trait because you should know those letters). Keep in mind that one letter (allele) came from each parent.

**Remember that your prediction for the parent's genotype, must also work with any given phenotypic information (i.e. the letters should be able to match the physical appearance of the parent).*

6. In pea plants, yellow seeds (Y) are dominant and green seeds (y) are recessive. A pea plant with yellow seeds is crossed with a pea plant with green seeds. The resulting offspring have about equal numbers of yellow and green seeded plants. What are the genotypes of the parents?

Y = yellow → YY, Yy
y = green

PARENTS ARE Yy & yy

| | Y | Y |
|---|---|---|
| Y | YY | YY |
| y | Yy | Yy |

or

| | Y | y |
|---|---|---|
| y | Yy | yy |
| y | Yy | yy |

Y Y
y 100%.
y Yy

7. In another cross, a yellow seeded plant was crossed with another yellow seeded plant and it produced offspring of which about 25% were green seeded plants.
What are the genotypes of both parents?

| | Y | y |
|---|---|---|
| Y | YY | Yy |
| y | Yy | yy |

Yy x Yy = Parents

## Back (Test) Cross Explanation

*When an organism has the dominant phenotype, then its genotype can be either heterozygous or homozygous dominant (you can't tell by looking at it). This type of problem requires that we do a test cross using an homozygous, recessive organism. For example: In Dalmatian dogs, the gene for black spots is dominant to the gene for liver colored spots. If a breeder has a black spotted dog, how can she find out whether it is homozygous or heterozygous spotted dog? *B = black spots and b = liver spots*

*If the breeder finds a black spotted dog, whose ancestry is not known, he cannot tell by looking at the dog if it is BB or Bb. She should find a liver spotted dog, whose genotype must be "bb" and mate it with the black spotted dog in question.*

*From this cross there are two possible outcomes. See the two Punnett squares on the next page.*

**If the suspect dog was heterozygous**

| | B | b |
|---|---|---|
| b | Bb | bb |
| b | Bb | bb |

*As you can see from the Punnett square, you would expect to have 50% black and 50% liver spotted.*

**If the suspect dog was homozygous**

| | B | B |
|---|---|---|
| b | Bb | Bb |
| b | Bb | Bb |

*If <u>any</u> of the offspring has liver spots, then we can say with <u>certainty</u> that she had a heterozygous black spotted dog. If <u>all</u> the offspring had black spots then we can say that the suspect dog was most likely homozygous.*

8. You found a wild, black mouse. Explain how you would determine the genotype of this mouse. * *hint in mice, white fur is recessive.* → cross the dominant w/ a recessive

a. Draw Punnett squares for your possible crosses.

| | B | B |
|---|---|---|
| b | Bb | Bb |
| b | Bb | Bb |

or

| | B | b |
|---|---|---|
| b | Bb | bb |
| b | Bb | bb |

b. You have ~~24 offspring~~, 23 with black fur and 1 with white fur. What was the genotype of the mouse? Bb

c. If you only had 3 black offspring, can you tell what the genotype was of the suspect mouse? Explain why or why not.

No, there are too few offspring to form a conclusion

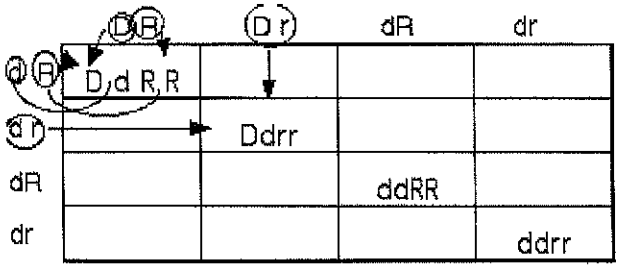
## Part II - DIHYBRID CROSSES Explanation

*When we study two traits at a time, we call this a <u>dihybrid</u> cross. You still follow the five steps but now there will be more possibilities because we are studying two traits.*

E.g. A female guinea pig is heterozygous for both fur color and coat texture is crossed with a male that has light fur color and is heterozygous for coat texture. Dark fur color is dominant (D) and light fur (d) is recessive. Rough coat texture (R) is dominant, while smooth coat (r) is recessive.

Step 1: *The guinea pig that is heterozygous for both color and texture. This means it has one allele for each trait. Therefore its genotype would be "DdRr". The other guinea pig has light fur, since that is a recessive trait the genotype for that trait must be "dd". It is also heterozygous for fur texture, which means a genotype of "Rr". All together its overall genotype must be "ddRr".*

Step 2 and 3: *The Punnett square will be larger now because there are more possible sperm and egg combinations. During the formation of sperm a "D" could go with a "R" producing a sperm "DR", or a "D" could go with a "r" forming a sperm with "Dr".*
*Filling-in the Punnett square it should look like the one we started below . Finish off filling in the blank squares in the Punnett square.* ***Remember:*** during meiosis, only one allele for each gene can go into the gametes (sperm or egg cells.)




*Step 4: After filling-in the Punnett square you should obtain the following genotypic ratio:*
*4 DdRr : 2 DdRR : 4 ddRr : 2 ddRR : 2 Ddrr : 2 ddrr*

*Step 5: The 4 DdRr and the 2 DdRR will have* ***dark*** *fur with* ***rough*** *coat, the 4 with ddRr and the 2 ddRR will have* ***light*** *fur with* ***rough*** *coat, the 2 Ddrr will have* ***dark*** *fur with* ***smooth*** *coat and the 2 ddrr will have* ***light*** *fur with* ***smooth*** *coat.*
*Therefore the phenotypic ratio would be:* ***6 dark, rough : 6 light rough : 2 dark smooth : 2 light smooth.***
***** These can be reduced to 3:3:1:1.***

**9. In pea plants, the round seed allele is dominant over the wrinkled seed allele, and the yellow seed allele is dominant over the green seed allele. The genes for seed texture and those for seed color are on different chromosomes. A plant heterozygous for seed texture and seed color is crossed with a plant that is wrinkled and heterozygous for seed color.**
****R = round, r = wrinkled, Y= yellow, y = green***
**a. Construct a Punnett square for this cross.**

RrYy × rrYy

R = round
r = wrinkled

Y = yellow
y = green

RY
Ry
rY
ry

rY
ry

| | RY | Ry | rY | ry |
|---|---|---|---|---|
| rY | RrYY | RrYy | rrYY | rrYy |
| ry | RrYy | Rryy | rrYy | rryy |

**b. What are the possible phenotypes of the seedlings?**
Round Yellow : Round Green : Wrinkled Yellow : Wrinkled Green
3 : 1 : 3 : 1

**c. What is the phenotypic ratio of offspring would you expect?**

10. In humans, there is an enzyme that breaks down the amino acid phenylalanine. E will represent the allele for the normal enzyme. However, there is a recessive allele (e) that produces a nonfunctioning enzyme. If a person is homozygous recessive (ee) they will have a disease called Phenylketonuria (PKU). This disease can result in mental retardation or death. There is another human disorder called galactose intolerance or galactosemia, which is also caused by a recessive allele (g). Let "G" represent the normal allele for the galactose digesting enzyme. If two adults were heterozygous for both traits (EeGg), what are the chances of having a child that is completely normal? Has just PKU? Has just galactosemia? Has both diseases?

E normal
e = abnormal
G = normal g = disease

EeGg
EG Eg eG eg

| EG | Eg | eG | eg |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**PART III. Incomplete Dominance or Codominance**

Both Normal : Normal Gal : PKU Normal : Both disease
9 : 3 : 3 : 1

Four o'clock flowers show incomplete dominance. A red four o'clock flower (r) is crossed with a white flower (w). *Since there is no dominant trait we use little letters for the genotype.*

Step 1: *The genotype of the red flower will be "rr" and the genotype of the white flower is "ww".*

Step 2 and 3: *Complete a Punnett square for this cross.*

| | r | r |
|---|---|---|
| w | rw | rw |
| w | rw | rw |

Step 4: *All of the offspring will be "rw". So the genotypic ratio is :* **4 : 0 : 0** RW WW rr

**4 : 0**
Pink other

Step 5: *All of the offspring will have one of each allele (rw), so all will be pink.*

11. Cross two pink Four o'clock flowers

a. Complete a Punnett square for this cross.

| | R | w |
|---|---|---|
| R | RR | Rw |
| w | Rw | ww |

b. What is the predicted genotypic ratio for the offspring? rr : rw : ww
1 : 2 : 1

c. What is the predicted phenotypic ratio for the offspring?
1 red : 2 Pink : 1 white

12. In humans straight hair (ss) and curly hair (cc) are codominant traits, that result in hybrids who have wavy hair (sc). Cross a curly hair female with a wavy haired male.

a. Complete a Punnett square for this cross.

| | C | C |
|---|---|---|
| C | CC | CC |
| s | CS | CS |

b. What are the chances of having a curly haired child?
50%

c. What genotype(s) would you need to produce a curly haired child?
cc male

## Part IV Multiple Allele

So far we have studied traits that are coded for only two alleles. However, some traits are coded for by more than two alleles. One of these is blood type in humans.
In human, there are four types of blood; type A, type B, type AB, and type O. The alleles A and B are codominant to each other and the O allele is recessive to both A and B. So a person with the genotype aa or ao will have A type of blood.

13. What possible genotypes will produce B type of blood? BB or BO

b. What is the only genotype that will produce O type of blood? OO

c. What is the only genotype that will produce AB type of blood? AB

14. You have blood type O and you marry a person with blood type AB.
a. Complete a Punnett square for this cross.

| | A | B |
|---|---|---|
| O | AO | BO |
| O | AO | BO |

b. List the possible blood types (phenotypes) of your offspring. Type A & Type B

15. In the 1950's a young woman sued film star/director Charlie Chaplin for parental support of her illegitimate child. Charlie Chaplin's blood type was already on record as type AB. The mother of the child had type A (ao) and her son had type O blood (ii or oo).

a. Complete a Punnett square for the possible cross of Charlie and the mother.

| | A | B |
|---|---|---|
| A | AA | AB |
| O | AO | BO |

b. The judge ruled in favor of the mother and ordered Charlie Chaplin to pay child support costs of the child. Was the judge correct in his decision based on blood typing evidence? Explain why or why not. **refer to any Punnett squares to support your answer.*

No, it was not possible for Charlie to have an "O" child

16. Suppose two newborn babies were accidentally mixed up in the hospital. In an effort to determine the parents of each baby, the blood types of the babies and the parents were determined.

| | | |
|---|---|---|
| Baby 1 had type O | Mrs. Brown had type B | Mrs. Smith had type B |
| Baby 2 had type A | Mr. Brown had type AB | Mr. Smith had type B |

| | B | O |
|---|---|---|
| B | BB | BO |
| O | BO | OO |

| | A | B |
|---|---|---|
| B | AB | BB |
| O | AO | BO |

a. Draw Punnett squares for each couple (you may need to do more than 1/ couple)

b. To which parents does baby #1 belong? Why? MR + Ms. Smith

## PART V SEX LINKED TRAITS

*As many of you know boys are different than girls. In humans sex is determine by the twenty third pair of chromosomes known as "sex chromosomes". If at conception you have two x-shaped (**XX**) chromosomes you are destined to be a female. If you have an x and a y-shaped (**XY**) chromosomes you are destined to be a male. Since the **X** and **Y** chromosomes carry different information, any genes found on the **X** chromosomes are referred to as **sex-linked genes.** Therefore, women will have two alleles for these genes because they have two (**XX**) chromosomes. On the other hand, men have only one allele for each of these genes because they have only one x chromosome (**XY**).*

**E.g.** In fruit flies, the gene for eye color is carried on the **X** chromosome which is a sex chromosome (sex-linked). The allele for red eyes is dominant over the allele for white eyes. If a white-eyed female fruit fly is mated with a red-eyed male, predict the possible offspring.

Step 1: *Since the female has white eyes, she must be "rr". The male is red-eyed and we were told it is a sex linked allele, therefore it is only found on the X chromosome. This means he only has one allele for eye color, so he must be "R". Since the allele "R" is present on the X chromosome only, and there is no other allele for eye color because the male other sex chromosome is a Y chromosome.*

Step 2: *For sex-linked traits we need to list the genotype in a different fashion. We must identify the individual as being male or female according to their sex chromosomes. Females are XX, and males are XY. Sex-linked traits are only found on the X chromosome, therefore the letters are placed superscript (above) to the X chromosome. Therefore the genotype for the female fly is $X^rX^r$ and the male is $X^RY$.*

Step 3: *I've set up a Punnett square for the parent flies (see below).*

| | $X^r$ | $X^r$ |
|---|---|---|
| $X^R$ | $X^RX^r$ | $X^rY$ |
| $X^r$ | $X^RX^r$ | $X^rY$ |

Step 4: *The genotypic ratio is* 1 : 1; $X^RX^r$ $X^rY$

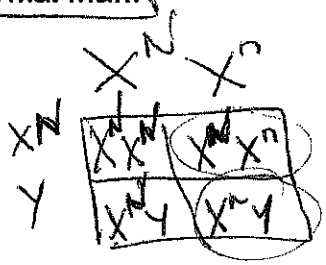
Step 5: *The individual* $X^RX^r$ *will be a female because she has two* **X** *chromosomes. She will have red eyes because she has* Rr. *The individual with* $X^r$ Y *will be a male because he has the* **X** *and* **Y** *chromosomes. He will have white eyes because he has only one allele and it is "r". So from this cross you would expect all of the females to have red eyes and all of the males to have white eyes.*

**17. Hemophilia is a sex-linked trait. A person with hemophilia is lacking certain proteins that are necessary for normal blood clotting. Hemophilia is caused by a recessive allele so use "N" for normal and "n" for hemophilia. Since hemophilia is sex-linked, remember a woman will have two alleles ($X^NX^N$ or $X^NX^n$ or $X^nX^n$) but a man will have only one allele ($X^N$ or $X^n$). A woman who is heterozygous (a carrier) for hemophilia marries a normal man.**

**a. What are the genotypes of the parents?**

$X^NX^n$ & $X^NY$

**b. Make a Punnett square for the above cross.**




**c. What is the probability that a male offspring will have hemophilia?** 50%.

**d. What is the probability of having a hemophiliac female offspring?** 0%.

18. Can a color blind female have a son that has normal vision? Color blindness is caused by a sex-linked recessive allele. **use N = normal vision and n = color blind* No

19. Baldness is a sex-linked trait. What parental genotypes could produce a bald woman?
**use H = normal hair, and h = bald*

$X^{H}X^{h} \cdot X^{H}Y$ & $X^{h}X^{h} \cdot X^{h}Y$

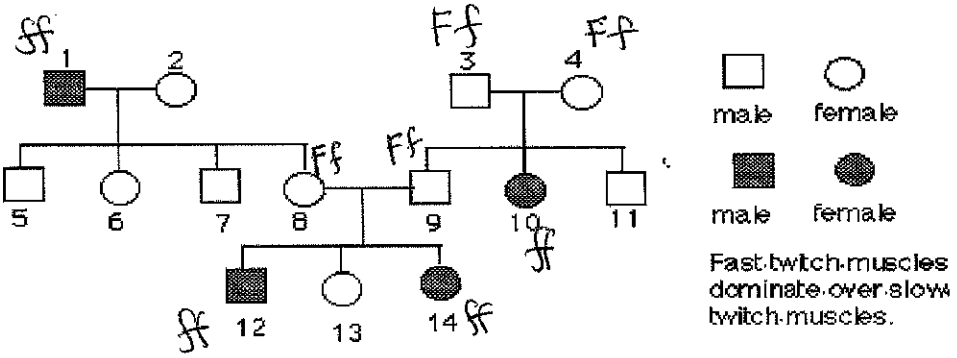
**Part VI: Pedigree Charts:**

*In genetics, traits can be traced over several generations similar to a family tree. This family tree is called a Pedigree chart. Pedigree charts are useful in gathering background genetic information that can be used for medical reasons. Horse race enthusiasts also rely heavily on pedigree charts to predict a horses success. Examine the following pedigree chart for eye color inheritance between two families. The lines between a circle and a square indicate parents, and the circles and squares directly below are their offspring.*

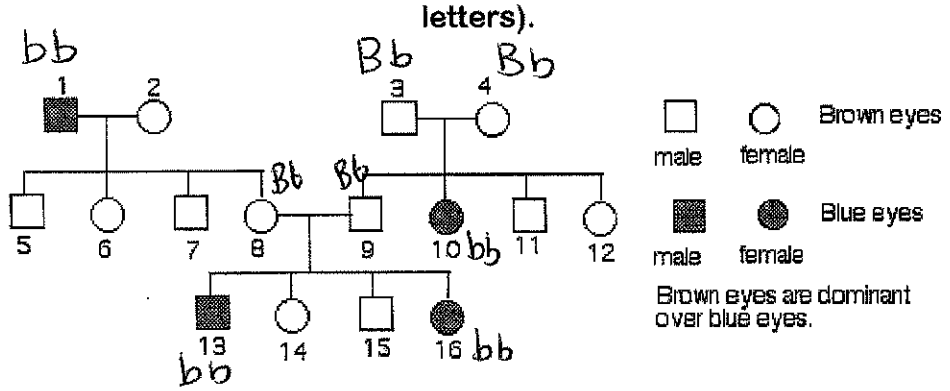
Step 1: *When solving pedigree charts begin with listing genotypes of **shaded** squares or circles, because they are **recessive** traits, therefore they must both be **small letters.***
Step 2: *If it is a child that is shaded, then place one small letter on each of its parents. If the parents aren't shaded then they must both be heterozygous.*
Step 3: *If it is a parent that is shaded, then place one small letter on each of its offspring. If none of the children are shaded then they must all be heterozygous, this means that the other parent who was not shaded must have been homozygous dominant.*
Step 4: *Repeat first three steps throughout the chart.*

20. Use the below pedigree chart to answer the following two questions. Muscle type is not a sex linked characteristic.

a. What is the genotype of individual #3 and 4? Explain your answer. Ff
b. Can either individual #8 or 9 be homozygous? Explain why or why not. No



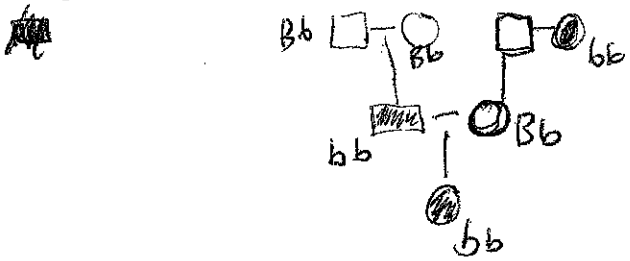

21. Label each genotype on the below numbered pedigree chart (note: eye color is **not** a sex-linked trait therefore you don't have to worry about combining XY or XX with genotype letters).



22. A blue-eyed man (1) whose parents were brown eyed (2 & 3), marries a brown eyed woman (4), whose father was brown eyed (5) and whose mother was blue eyed. They have one female child who is blue eyed (6). Blue eyes are recessive.

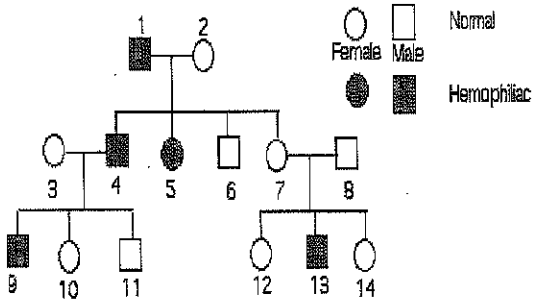
a. Make a pedigree chart based on the above information.

Blue eyes




b. Label the genotypes of the individuals in the chart.

23. List the possible genotypes of the following hemophilia pedigree chart below. **Remember hemophilia is a sex linked trait that is caused by a recessive allele, therefore you must denote the individuals sex chromosomes ($X^NX^n$ and $X^nY$ or Nn and nY) as well as the hemophilia allele (n).**




| | | |
|---|---|---|
| 1 $X^nY$ | 6 $X^NY$ | 11 $X^NY$ |
| 2 $X^NX^n$ | 7 $X^NX^n$ | 12 $X^NX^n$ ? |
| 3 $X^NX^n$ | 8 $X^NY$ | 13 $X^nY$ |
| 4 $X^nY$ | 9 $X^nY$ | 14 ? |
| 5 $X^nX^n$ | 10 $X^NX^n$ | |

24. Examine the following pedigree chart of colorblindness. In humans, color blindness is caused by a **recessive sex-linked** allele. On the diagram, label the genotypes of the individuals 1-16.